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EVALUATION OF SOME AGRONOMIC LAND-USE PRACTICES ON SOIL QUALITY INDICATORS AROUND AMALLA-NSUKKA AREA, SOUTHEAST NIGERIA

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Abstract

Information about effects of agricultural land uses on soil properties is essential for sustainable utilization of soil resources and conservation of the ecosystem. This study was carried out to assess the impact of agricultural land use types on selected quality indicators of some soils of Amalla in Nsukka, South-East Nigeria. A total of 15 composite soil samples were collected each from cassava farm, maize farm and oil-palm plantation farm at 0-15 cm soil depths in 5 different study locations. Three farms practicing each of the land use type at each location were taken as replicates. The analysis of variance (ANOVA) was done following the generalized linear model of Statistix 9.1 laid in a Completely Randomized Block Design. The results shows that the mean values of sand, silt and clay contents ranged from 74.60–80.80%, 11.00–14.00% and 7.39–11.40% in the farm locations, respectively. The mean soil bulk density ranged from 1.18–2.05 g/cm^3 and was significantly ($P<0.05$) different among the land use types, except at Ibagwa farm. The sand and silt contents of the soils did not differ significantly ($P<0.05$) among the land use types in most of the study locations. The clay content differed significantly across all land use types in all the sampled locations, and was significantly higher under the oil palm compared to both cassava and maize farming systems. The significantly ($P<0.05$) higher soil organic carbon (OC) content was found under the oil palm land use, while the lowest organic carbon of 0.34% was found in the cassava farm locations. Soil organic matter (OM) was significantly ($p \leq 0.05$) higher in the oil palm (2.1% – 2.9%) and lowest under the cassava farm (0.59%–1.3%). Generally, the OC content (0.34%–1.34%) recorded under the various land use types was well below the bench mark for most crop requirements, and soil's structural stability might fail. The soils are thus, predisposed to greater risk of low fertility and water erosion. More detailed studies on environmental and economic aspects of these land uses are strongly recommended.

Key words**:** *evaluation, agronomic land use, soil quality indicators, Amalla, Southeast Nigeria*

INTRODUCTION

Change in land use management from natural to managed ecosystems often attracts consequences that may be deleterious to soil structure and other inherent soil qualities. Over the years, soil quality and sustainable agricultural productivity have largely been depleted by inappropriate land use management systems [4]. Accordingly, agricultural management practices can largely influence the quality of soils which in turn affects sustainability of agro-ecosystem roles on crop productivity [9]. Land use change affects the dynamics of soil nature and is one of the main drivers of environmental change as well as important component in understanding the sequence of changes in the characteristics and interaction of human activities in the environment. These changes affect the basic nature of the land and several other natural processes in the soil. A successful agriculture thus, requires a sustainable use of soils, but poor land use practices could easily cause soil to lose its quality within a short period of time [20]. However, the success to preserving soil quality widely depends on the understanding of how the soil responds to agricultural practices over time [10]; and as such, agricultural practices requires basic knowledge of sustainable use of land [37].

According to [20], land use may be the most dominant factor that influences soil properties under small catchment scales. Land use and soil management practices influence the soil nutrients and related soil processes such as erosion, oxidation, mineralization, and leaching, among other processes [6], [22]. The introduction of the sand to clay ratio was noted as the main soil physical factor controlling the aggregate stability against erosion [23], while increase in sand content in soils was reported to decrease their susceptibility to gully erosion [14]. But for heavy soils containing large amounts of clay and silt particles due to increase in the saturation water and water holding capacity, the formation of gully erosion and their frequency are more expected [14].

Most changes in land use affect the amount of carbon held in vegetation and soil. The soil organic matter (OM) and the organic carbon (OC) plays crucial roles in enhancing crop production [36], and in the mitigation of greenhouse gas emissions [15]. Furthermore, OC contents of soil aggregates influence aeration, water movement, and nutrition, while the soil OC contents of bulky soils affects water-holding capacity [7]. Thus, maintenance of soil OM is especially important due to its effect on soil nutrient status and soil structural stability [11].

The Southeastern ecological zone of Nigeria has a human population considered to be a factor in moderating human roles on land use patterns as well as per-capital consumption [26], [2]. The high population increase now poses a number of threats to provision of adequate food supplies, management of soils to support crop production, development of appropriate technologies for sustainable agricultural production and meeting the challenges of intensive agriculture. Despite the use of mineral fertilizer blends such as NPK and Urea fertilizers on soils of the region, the yields of crops are still in constant decline and has become a source of concern. At present, there is no information available to the people of Amalla area on the immediate and remote causes of low crop yields in recent times.

The sustainability of crop and soil management practices that could improve soil quality depends on understanding how soils respond to different site-specific cropping and land-use practices [29]. Consequently, there is need for adequate soil information to understand and appreciate the serious issue of sustaining soil productivity in the south-east region of Nigeria. The most prevalent land use patterns in communities of the south-east Nigeria, such as Amalla in Enugu State, include continuous cassava and maize cultivation, and several oil palm plantations. This research was, therefore, focused on assessing the effects of some of the practiced land use types on soil OC content, plus other soil physical properties and their potentials for continuous agriculture in the study area.

MATERIALS AND METHODS

The study area

The study was conducted in Amalla area located in Udenu Local Government Area (LGA), and forms part of the Nsukka Senatorial Zone of Enugu State. The area is located between Latitudes 6^o 55'' and 6^{o}50'' N and between Longitudes 7^{o}30'', and 7^{o}35'' E of the equator. The climate of the study area is sub-humid tropical, having distinct rainy and dry seasons, with a bi-modal rainfall distribution pattern with peaks in July and September. The month of March is the warmest with an average temperature of 27^{o}C, while the month of August is the coldest with an average temperature of 22.9^{o}C [28]. The mean annual minimum rainfall is 1,200 mm, while the mean annual maximum rainfall is 2,000 mm spread between April and early November.

The natural vegetation consists mainly of secondary forest due to prolonged human intervention through arable small scale farming methods. The predominant crops grown include cassava, maize, oil palm, banana, and cocoyam among others. Farming is the major socio-economic activity in the area. The farm area has a wide expanse of one square-mile of which about 85 hectares are being cultivated for arable crop production. Arable crops are mostly cultivated and are grown as rain-fed crops. Major crops grown are maize (*Zea-mays*), cassava (*Manihot spp*), and Oil Palm (*Elaeise guinnensis*).

Site selection and soil sampling procedure

Field reconnaissance survey was carried out during the 2019 cropping season in the study area to select farm stations with different land uses. Direct interviews were held with the farmers to gather information about the area over the past 5 years. The interview was done for each farm unit that was eventually selected for the study.

Three farms used for the cultivation of cassava (*Manihot spp*), Maize (*Zea mays*) and Oil palm (*Eleais guenensis*) were sampled in each of the 5 selected villages comprised of Ibagwa, Obodo-onitsha, Umua-gbadu, Umu-enachi and Ifuroka. Within each farm, 4 soil samples were collected randomly at a 0-15 cm depth using an Edelma soil auger, then homogenized thoroughly to give a composite soil samples as a representation of each farm. Thus, a total of 15 representative soil samples were collected for each land use type. Each soil sample was kept in a black polythene bag and properly labelled. The samples were subsequently transported to the laboratory, air dried, crushed and sieved using a 2 mm mesh sieve in preparatory for laboratory determination of the selected soil properties.

Determination of selected soil properties

The bulk density was measured following the core method as described by [43]. Particle size distribution was determined using Bouyoucous hydrometer method [17], while the soil OC was determined using the Walkley and Black wet oxidation method using a 1-normal potassium dichromate (1N $K_2Cr_2O_7$) as described by [25]. The soil OM content was then computed by multiplying the OC content by a factor of 1.724.

Statistical Analysis

The data generated was analysed in accordance with the generalized Linear model of Statistix 9.1 (2012) for the ANOVA in a completely randomized block design (CRD). The sample means were compared using a Standard error (SE) and then separated using the Least Significant Difference (LSD) in order to determine the influence of the land use types on the measured soil properties.

RESULTS AND DISCUSSIONS

Effects of land use types on selected soil properties in the study area

Particle size distribution

Results of the effects of land use types on some selected soil properties across the study locations are shown in Tables 1- 5. Tables 1-3 show the results of selected soil properties as influenced by the land use types at Ibagwa, Obodo-onitsha, and Umu-enachi locations, while Tables 4 and 5 show the results for Umu-agbadu and Ifuroka locations, respectively.

Table 1. Effects of land use types on selected soil properties at Ibagwa village farm location

Land use type	**PSD (%)**			**Soil texture**	**BD (gcm^{-3})**	**PD (gcm^{-3})**	**OC (%)**	**OM (%)**	**OM rating***
	Sand	Silt	Clay						
Cassava farming	79.60^a	12.50^a	7.90^b	Loamy sand	1.39^a	1.12^a	0.62^c	1.0^b	Medium
Maize farming	79.59^a	13.00^a	7.39^b	Loamy sand	1.36^a	1.12^a	0.73^b	1.26^b	Medium
Oil Palm farming	76.59^a	12.01^a	11.40^a	Loamy sand	1.47^a	1.12^a	1.34^a	2.31^a	Very high
SE (±) P<0.05	NS	NS	0.8165		NS	NS	0.0128	0.0134	

Means followed by different letters in the same column are significantly different at probability level (P<0.05).
*Murphy *et al.* (2012)
Key: PSD = Particle Size Distribution; BD = Bulk density; PD = Particle density; OC = Organic carbon; OM = Organic matter
Source: Authors' results.

Table 1 shows that the sand and silt contents did not differ significantly (P<0.05) among the land use types in Ibagwa location, except for clay content that differed significantly (P<0.05). The results also show that sand content (76.59-79.60%) predominated the soil textures, followed by silt (12.01-12.50%) and clay contents (7.39-11.40%).

Table 2. Effects of land use types on selected soil properties at Obodo-onitsha village farm location

Land use type	PSD (%)			Soil texture	BD (gcm^{-3})	PD (gcm^{-3})	OC (%)	OM (%)	OM ratings
	Sand	Silt	Clay						
Cassava farming	74.60[a]	13.00[a]	7.40[a]	Loamy sand	1.48[b]	1.05[a]	0.78[c]	1.3[b]	Medium
Maize farming	79.59[a]	11.86[a]	8.40[a]	Loamy sand	1.69[a]	1.08[ab]	1.06[b]	1.8[b]	High
Oil Palm farming	80.60[a]	12.00[a]	7.40[a]	Loamy sand	1.26[c]	1.21[a]	1.23[a]	2.1[a]	Very high
SE (±) P<0.05	NS	NS	NS		0.0428	0.0519	9.03E-03	0.0152	

Source: Authors' results.

Results for Obodo-onitsha location shown in Table 2, reveals that sand, silt and clay contents did not differ significantly (P<0.05) among the land use types. Likewise, results for Umu-Enachi village is presented in Table 3, and it shows that sand, silt and clay contents differed significantly (P<0.05) among the land use types. However, sand content still dominated the textures, followed by silt and clay contents, respectively.

Table 3. Effects of land use types on selected soil properties at Umu-Enachi village farm location

Land use type	PSD (%)			Soil texture	BD (gcm^{-3})	PD (gcm^{-3})	OC (%)	OM (%)	OM ratings
	Sand	Silt	Clay						
Cassava farming	76.60[c]	14.00[as]	7.39[a]	Sandy loam	1.18[b]	1.16[a]	0.34[c]	0.59[c]	Very low
Maize farming	79.30[a]	11.00[b]	9.41[a]	Sandy loam	1.23[ab]	1.11[a]	0.62[b]	1.07[b]	Low
Oil Palm farming	78.76[b]	12.01[ab]	9.20[b]	Sandy loam	1.28[a]	1.09[a]	1.06[a]	1.83[a]	Medium
SE (±) P<0.05	0.0318	0.8166	0.0109		0.0288	NS	8.17E-03	0.0113	

Source: Authors' results.

Table 4. Effects of land use types on selected soil properties at Umu-Agbadu village farm location

Land use type	PSD (%)			Soil texture	BD (gcm^{-3})	PD (gcm^{-3})	OC (%)	OM (%)	OM ratings
	Sand	Silt	Clay						
Cassava farming	80.80[a]	10.97[a]	8.20[a]	Loamy sand	2.02[b]	1.06[a]	0.34[c]	0.59[c]	Low
Maize farming	80.30[a]	12.00[a]	7.70[a]	Loamy sand	1.24[c]	1.04[a]	0.73[b]	1.26[b]	Medium
Oil Palm farming	79.80[a]	12.00[a]	8.20[a]	Loamy sand	2.05[a]	1.07[a]	1.28[a]	2.22[a]	Very high
SE (±) P<0.05	NS	NS	NS		0.0100	NS	8.17E-03	0.0341	

Source: Authors' results.

The results of Umu-Agbadu location presented in Table 4 shows that sand, silt and clay contents did not differ significantly (P<0.05) among the land use types. The results also show that sand content (79.80-80.80%) still predominated the soil textures, followed by silt (10.97-12.00%) and clay contents (7.70-8.20%).

For Ifuroka location, the results presented in Table 5 shows that both sand and clay contents did not differ significantly (P<0.05) among the land use types, except under cassava farming system, which differed significantly from the other land use types.

Table 5. Effects of land use types on selected soil properties at Ifuroka village farm location

Land use type	PSD (%)			Soil texture	BD (gcm^{-3})	PD (gcm^{-3})	OC (%)	OM (%)	OM ratings*
	Sand	Silt	Clay						
Cassava farming	79.80^{a}	11.70^{ab}	8.50^{a}	Loamy sand	1.38^{b}	1.07^{a}	0.45^{b}	0.78^{b}	Low
Maize farming	79.80^{a}	12.00^{a}	8.69^{a}	Loamy sand	1.41^{a}	1.08^{a}	0.45^{b}	0.78^{b}	Low
Oil Palm farming	80.80^{a}	10.50^{a}	8.70^{a}	Loamy sand	1.42^{a}	1.05^{b}	0.66^{a}	2.90^{a}	Very high
SE (±) P<0.05	NS	0.3392	NS		9.43E-03	4.3E-03	9.81E-03	0.0249	

Source: Authors' results.

The results also show that the soils of the study area are generally Loamy sand textured, except for Umu-enachi location (Table 3) which falls in the Sandy loam category. The sand and clay fractions did not differ significantly (P<0.05) among the land use types across all study locations, except for Umu-Echina location. Likewise, silt did not differ significantly (P<0.05) among the land use types in the study locations, except for Umu-Echina and Ifuroka.

Although there was no statistical disparity among the sand contents under most of the land use types in the study locations, there was, however, numerical variation among the land use types. Sand particles was found as the soil property that was slightly influenced by some of the cropping and land use systems, in addition to other activities such as soil erosion-deposition processes [38]. This present finding on soil texture was consistent with those of [35], who reported that there was no significant effect of land-use systems on soil particle size distributions. However, this report did not agree with some findings by [19], [41] and [1], who reported that continuous cropping and intensive land-use systems have significantly affected soil particle size distributions. Recently, it was highlighted that such discrepancy in the soil particles could be attributed to the duration of the cropping system for a given land use, variability in management practices, effects of weather conditions, plus the influence of variation in topography [38].

The high sand content recorded in soils of the study areas was perhaps, due to the intensive agricultural practices. The sand content ranged closely with those reported by [16], who found higher sand contents in the surface layers of cultivated lands. Clay content of the various soils, though generally low (7.39%-11.40%), still varied significantly among the land use types. The significantly (P<0.05) high differences in clay content especially between the oil palm farming system and those of both cassava and maize farming systems was perhaps, due to less pulverization of soils under oil palm farm, than for both maize and cassava farms. Similar finding was observed by [16], who reported that plantation farm recorded higher clay content than on arable farms. Clay material help to provide the needed cohesion among soil particles, resulting in the formation of more stable aggregates which makes them less susceptible to erosion [27]. The absence of clay fraction reduces the tendency of soil particles to bind together and form soil aggregates that are resistible to the shearing force of flowing water, thus making the soil more vulnerable to soil erosion. However, it was reported that soils with more sand and silt proportions than clay (as observed in this study) at the surface layer promotes runoff, and are hence, susceptible to water erosion [39].

Bulk density

Bulk density differed significantly (P<0.05) among the land use types across all locations, except for Ibagwa location, where bulk density of the soils did not differ significantly (P<0.05) among the land use types. Highest bulk density of 2.05 gcm^{-3} occurred under the oil palm farming system, while the lowest value of 1.18 gcm^{-3} occurred under the cassava farming system at Umu-Enachi location. In the locations, soil bulk density was significantly (P<0.05) higher under the oil palm land use type. Differences in the bulk density of the soils could be the result of varying degree of soil disturbances experienced under the respective land use types. The relatively higher bulk density under the oil palm land use could be as a result of less tillage activity that left the soils undisturbed to have increased its compactions over time. The intensive cultivation of the cassava and maize farming systems and the attendant applications of fertilizer could have contributed to their lower bulk densities, since farming activities in the region are not done with heavy machineries that could trigger soil compaction over time. However, values of the bulk densities recorded across the study locations, with the exception of Umu-Agbadu, falls within the critical level described as an ideal soil condition for plant root growth and water holding capacity [3]. Bulk density is a combined result of soil structure, texture, OC and applied pressure on soil [42], [40], and is necessary for the estimation of some physical soil properties, including porosity, water retention, heat capacity, and compressibility [33].

Soil OC Content

The significantly ($P<0.05$) higher soil OC contents was both found under oil palm land use system at Ibagwa (1.34 %), followed by Umu-Agbadu (1.28 %), while the lowest OC of 0.34 % was found under the cassava land uses at Umu-Enachi and Umu-Agbadu locations. The soil OC content varied significantly ($P<0.05$) among the various land use systems across the study locations. The cassava land use system recorded the lowest OC content across the locations, followed by maize farming system. The relatively higher OC content observed under oil palm land use system could be the result of accumulation of litters in the topsoil surfaces and the slow uptake of mineralizable OM content. On the other hand, the relatively lower OC content under cassava and maize land use systems could be attributed to the continuous land cultivation that aggravates OM oxidation.

Soil OC had a significant ($P<0.05$) effect on the chemical and physical characteristics of the soils, and it is one of the most essential components for soil quality assessments. The OC content is accounted as an important indicator for determination of soil erodibility, which are often affected severely by land use change [12]. The impacts of land use change on soil OC, permeability and aggregate stability can trigger changes in the inherent soil erodibility statuses [18]. The OC content had positive effects on soil water holding capacity and soil porosity, leading to reduction in soil erodibility [13]. The OC content (0.34%-1.34%) recorded in soils under the various land use types was well below the 2% critical limit suggested as a bench mark below which soil structural stability will suffer a significant decline [27]. According to [31], intensive tillage under rain-fed farming systems may increase aeration rates, which induces the acceleration of OC oxidations. This explains why lower values of OM content were recorded under both cassava and maize farming systems, as against the oil palm farming system across the locations studied. Similar findings were reported by other researchers who claimed that continuous cultivation depletes soil OC and reduces soil quality, regardless of the cropping system practiced [30]. According to [38], agricultural intensification and repeated cultivation have resulted into a serious decrease in soil OC content under natural vegetation. According to the authors, cultivation enhances decomposition of soil OC. The present study is in agreement with previous reports, such as [5] and [34], where variability in soil nutrient stocks was said to be attributed to differences in soil and crop management practices under different land use patterns.

Soil OM Content

Figure 1 shows the variations in soil OM with land use types and across locations.

Significant differences ($p \leq 0.05$) in soil OM content were observed among the land use types. The OM content was significantly ($P<0.05$) higher under oil palm (2.1% - 2.29%) farming system, and was the lowest under cassava farming (0.59% - 1.3%).

There was, however, relatively lower OM content (1.83%) under oil palm at Umu-Enachi, which could be as a result of the sandy loam texture, compared to the loamy sand texture at the other locations.

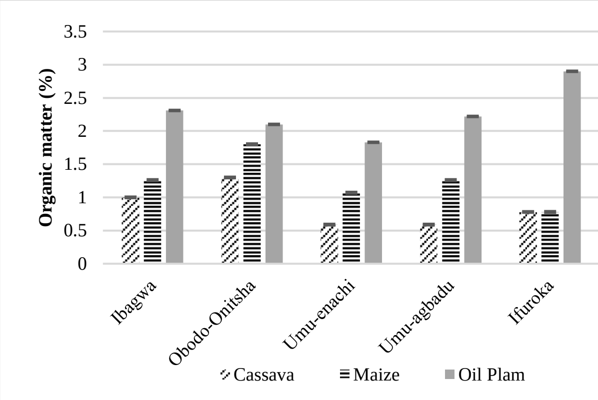

Fig. 1. Variation in OM with landuse types and across locations
Source: Authors' results.

The significantly low soil OM under cassava farming could be attributed to the effect of continuous cultivation of the soil, which promotes OM oxidation.

The higher OM content under the oil palm land use system could have been due to the shrub residues and litters, plus low utilization of OM content in the plantation. This result corroborate with the findings reported by [21], that cultivated soils generally contain relatively low OM content due to the action of soil aeration, which enhances decomposition of soil OM.

Following the ratings by [24], the soil OM were generally low to medium under the cassava farming, then low to high under the maize farm, and was medium to very high under the oil palm land use, respectively. Soil OM is recognized as a major component among soil quality indicators, and is linked to many other soil quality indicators that moderates crop productivity [30].

Soil OM plays an important role under long-term soil conservation and/or soil restoration towards sustaining soil fertility [8].

It is also credited to increasing structural stability of soils against rainfall erosive impacts, poor infiltration capacities, and in the activities of soil fauna [32].

CONCLUSIONS

This study evaluated some selected soil physical properties and OC content as affected by different land use types in 5 different locations in Amalla, Nsukka Senatorial District of Enugu State, South-East Nigeria. The soil textures of the study area was predominantly loamy sand, being largely of sand with low clay fraction. The sand and silt contents of the soils did not differ significantly ($P<0.05$) due to the land use types in most of the study locations, whereas clay differed among the land use types and across study locations. The soil bulk density was significantly ($P<0.05$) higher under oil palm land use type. Variation in soil qualities was influenced by the types of soil management practices studied. Soil OM content was significantly ($p \leq 0.05$) higher under the oil palm (2.1% – 2.9%) and lowesr under cassava farming (0.59% - 1.3%). Generally, the soils were low in OC (<2%) and clay (<12%) contents; a situation that can predispose the soils to greater risk of water erosion. While this work revealed changes in soil quality indicators under the land use types across study locations, a detailed study on environmental and economic aspects of these land uses is strongly recommended. Furthermore, measures to improve the soil OC content should be promoted to enhance resistance of the soils to water erosion and to overcome low soil fertility in the study area.

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